The ECMI Educational Programme in Mathematics for Industry: history, structure and perspectives

History

During the academic year 1986-1987, representatives of universities belonging to the European Consortium for Mathematics in Industry (ECMI) designed a two year postgraduate programme and reported the results in accounts dated 20-2-1987 and 20-3-1987. As intended, an educational programme which included exchange of students, exchange of teachers, central international courses and close cooperation with industry became operational. This original ECMI Educational program was planned at the time when the Bologna model was not yet established. This was almost like a "pathfinder project" in the line of the emerging Bologna Model. The program was initially called ECMI postgraduate programme in Math for Industry. In many countries this was initially understood as a two year extension after the first degree - which often was a Master's degree, Diploma, etc. This variability of study structures in European universities was also in many cases a hindrance to its implementation. The initial structure of ECMI postgraduate program was defined in a rather detailed rigorous manner. A list of recommended textbooks and model syllabi were published to emphasize the spirit and to set a standard of ECMI education. A thorough description of the Introductory Phase (required prerequisites for admittance) was published, to harmonize the entrance qualifications.

Such quality management was part of the initial idealism and determination of the founders. The vision of the time was to provide a standardized European brand. The real scale of variation in European academic life turned out to be a challenge. These matters were primary reasons why the adoption of ECMI model was slow and some member universities were not able to fit into the given frame. That was the reason for the need of various revisions, that we describe in the following.

After the first few years of implementation of the ECMI-educational system the single experiences were discussed in detail by its partners and they led to an agreement for small changes in the philosophy and execution of the original Programme. The resulting description, dated 17-8-1990, has been the guideline for the Programme for a period of about five years in which the educational system of ECMI was consolidated and gradually extended. The programme Mathematics for Industry initially placed emphasis on ODE's, PDE's and numerics and consequently on industrial problems that can be attacked by these mathematical techniques. When it became apparent that staff and students from the fields of Operation Research, Statistics and related areas would like to join the Programme (with an emphasis on these parts of mathematics, and consequently on other types of industrial problems) the Programme was again re-considered. The decision was taken, to reconstruct the programme so as to consist of two branches, closely linked together, of which the existing one was called "Technomathematics" and the new one "Economathematics". Contents of and interaction between the two branches as well as the way to arrange the execution of the international aspects have been discussed in several meetings of the Educational Committee; the final result has been approved in the meeting of the Council of ECMI on July 8, 1995.

The Programme with the two branches was then running for about 10 years, during which the number of ECMI Educational Centers increased, and the programme was also exported in other countries in Europe, also outside the EU, for example to Serbia, University of Novi Sad,via an EU funded Tempus Project, or, more recently, to Bulgaria (Sofia University) and Russia (St. Petersburg State Polytechnical University).

Starting from 2005, with the gradual revision of the educational programmes of European universities, according to the 3+2 Bologna Scheme, a need for a deeper revision of the ECMI Educational Programme emerged, giving rise to new projects, funded by the EU (in particular the Erasmus Mundus ESIM, and the Erasmus Curriculum Development ECMIMIM) to modify the programme in order also to facilitate the establishment of double or joint degree master programmes between the ECMI educational centers. The established Bologna Scheme, providing a standardization of the structure of European graduate programmes, gave a more natural frame to the ECMI Educational Programme as an ECMI Master Program.

Motivation

Let us describe the main motivations which led and still push the ECMI Centers to establish, maintain, and update the Educational Programme in Math for Industry.

In modern industry, mathematical methods play an increasingly important role in research and development, production, distribution and management. These methods come not only from classical applied mathematics (mathematical physics, continuum mechanics, numerical mathematics, probability theory and statistics), but also involve e.g. operations research, control theory, signal and image processing and cryptography. Furthermore, mathematicians are more and more involved in the formulation, analysis and evaluation of mathematical models. For this development at least three reasons can be given:

1. Industry in Europe is increasingly engaged in knowledge-intensive activities. Research and development are important and a certain sophistication in production is needed to keep the lead (flexible automation, optimization of products and production processes, quality control). Notice, that the word "industry" here and elsewhere in this description has to be interpreted in a broad sense, covering also e.g. transport, finance, medical science, information technology and

any activity with an economical, technological or societal impact.
2. The possibilities for the use of mathematical models are now superior to and more extensive than those of some decades ago. This is due to the rapid development of mathematical methods and to the increased capability of computers and their programming facilities.
3. Mathematics in industry has traditionally been exploited by engineers, chemists and physicists, with occasional support from a mathematician. Nowadays the need for more advanced mathematical methods, not familiar to those scientists, introduces an increased demand for industrial mathematicians.

It should be remarked, however, that it is rare for Mathematics to be used as an independent science for the benefit of an industrial company. The common situation is that Mathematics is called in to assist with the solution of problems that arise from other fields. For this reason, a mathematician often has to be member of an interdisciplinary team. A consequence is that the training of an industrial mathematician should contain communication techniques, knowledge of other disciplines and experience in teamwork.. This kind of mathematics is problem driven, not method driven.

Structure of the Programme

Here we present the structure of the Educational Programme which was running up to the recent revision in the 3+2 scheme. The main ingredients of the Programme are still contained in the new versions which have been developed after the ESIM and ECMIMIM projects.

Originally the programme was studied to fit a 5 years cycle of graduate studies, being concentrated on the last 2 years of the cycle.

Each student had and still has to complete the following components:

- A mandatory common core of course work, designed to give the student a command of basic mathematical tools emphasizing constructive aspects, and with problem solving and modelling as the primary goals. The sections that constitute the common core must be regularly offered at all participating institutions.
- An individual selection of special topics which may vary from center to center, according to the different local expertise.
- Practical training in mathematical modelling, organized in a regular modelling seminar. In addition, ECMI organizes yearly a Modelling Week where students from the participating institutions meet and work in international teams on industrial problems.
- A project thesis of at least half a year's work involving a real industrial problem, preferably carried out in an interdisciplinary environment, involving participants from Industry. Ideally, the thesis should demonstrate the candidate's ability to model the problem, to treat it with mathematical and computational tools and to present the results in a way understandable and useful to the client. To be acceptable, the project thesis must meet the standards of the profession with regard to each of these aspects. The thesis must be written in English and is reviewed by an expert appointed by the ECMI Educational Committee.
- A student exchange programme requiring each ECMI student to spend a period at another participating university or develop the final project abroad.

SHOULD WE NOT MENTION THE 60 :20 : 20 RULE???

Students successfully completing the previous requests are awarded of a Certificate by the ECMI Board.

The Two Branches

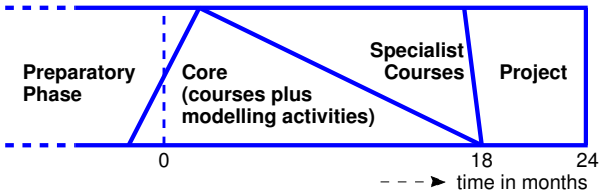
Since "Technomathematics" and "Economathematics" are artificial names, there is some need to describe in more detail what is meant by them. This description will focus on the relation between the two branches and provide some examples of subjects in industrial practice. It is in no way meant to draw a line, distinguishing types of mathematics or even of mathematicians. The description is, on purpose, not a sharp one, since in the Programme it is an advantage rather than a problem that certain subjects can be reached from either branch.

"Technomathematics" has to be considered as the part of the programme "Mathematics for Industry" in which real world physical, technological or biomedical problems are treated, in areas like e.g. heat exchange, fluid dynamics, electro-magnetic fields, polymer science, population dynamics. "Economathematics" on the other hand deals with problems like e.g. planning and scheduling, quality control, distribution management, financial decision processes, data communication and data mining.

The general policy is that the two branches have to be closely linked together. In any case, students from the different branches in the Programme must be able to "talk to each other". In order to reach this, the conditions for admission to the Programme have been made nearly the same for the two branches. The International Modelling Week is organized for both branches together.

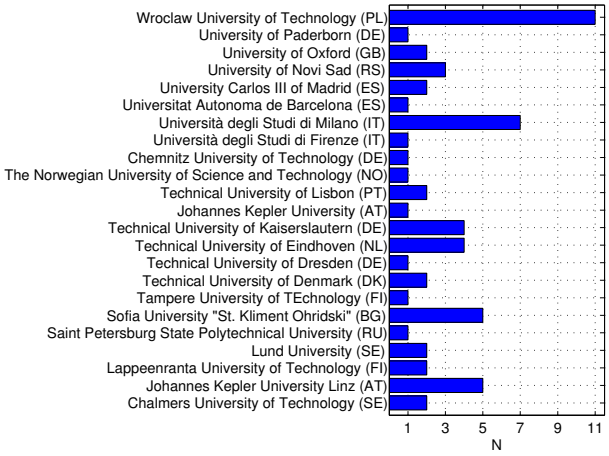
Time Schedule of the Programme

Since the very beginning, each branch of the Programme consisted of courses and problem-solving activities from its Common Core, courses of a specialist nature, and a project, and was planned to extend over a two year period. The Preparatory Phase was the range of knowledge which a student entering the Programme should have. However, it was recognized that the backgrounds of different students may be very varied and that most students would not have covered all the Preparatory Phase topics before commencing the Programme. Thus in each individual case it was expected that some topics in the Preparatory Phase would be studied during the Programme, and conversely that exemption of some courses of the Programme can be given when they are proved to be known from the preparatory university study. Further, there was no need for a strict order in time between the core courses and the specialist courses. This induced a time profile as follows:



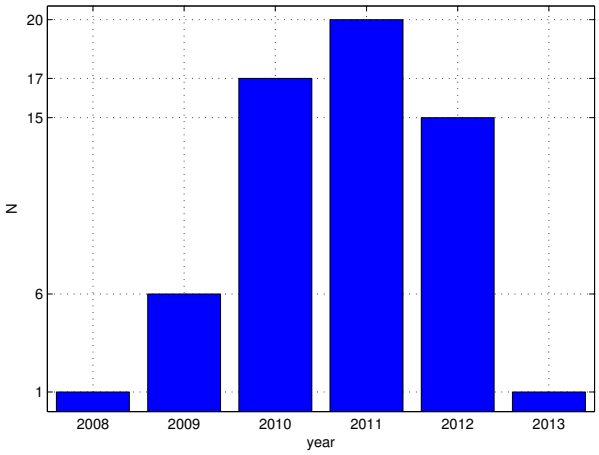
Survey on former ECMI graduates

Recently the ECMI Educational Committee has diffused a survey among the participants to the last 4-5 editions of the ECMI Modelling Week, in order to get the point of view of the former students of the ECMI centers who took part, at least partially, to the ECMI educational programme. In particular, questions concerning the importance of the main ingredients of the programme, i.e. modelling activities, an international experience, and the development of an industrial thesis, have been posed to the interviewed. We report here some commented results, which can be used as a starting point for possible future improvements of the programme.



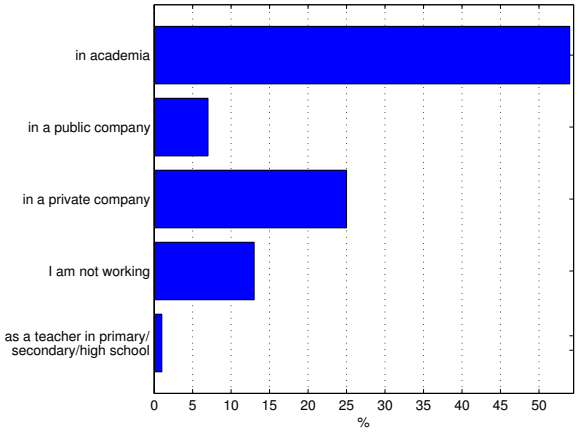
In which University did you graduate?

The students who answered to the survey came from many different European universities, some of which are still not fully recognized as ECMI Educational Centres. This means that many of these students have followed only partially the ECMI Educational Programme.

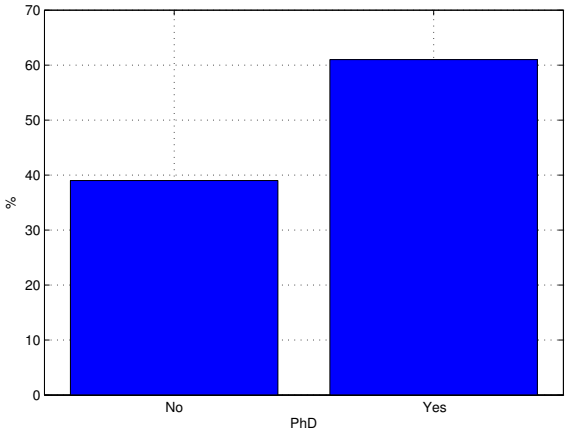


Year of graduation

These students have graduated quite recently, as we could expect from the chosen sample since typically the Modelling Week is followed at the end of the MSc studies.

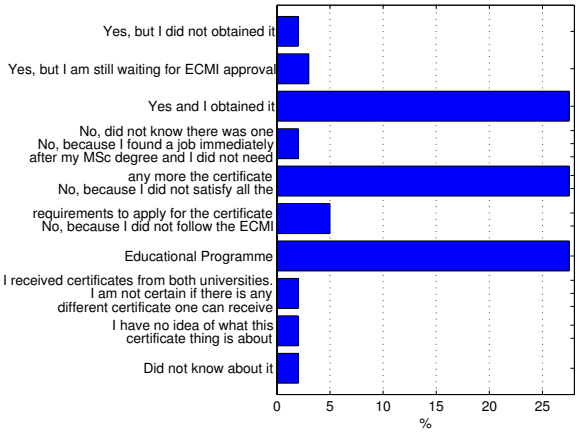


Presently you are "working"



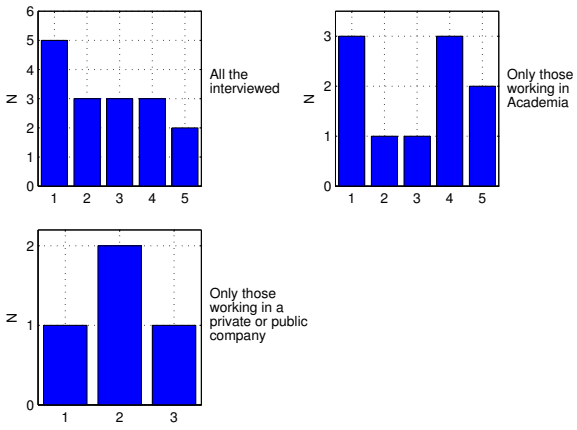
Do you have a PhD title or are you presently studying in a PhD programme?

About 60% of the interviewed former students continue their studies, typically with a PhD. This observation may reflect either the fact that in Europe the PhD level of instruction is more and more required to get a good job, or the fact that the students which are usually selected by the ECMI Centers to participate to the ECMI Modelling Weeks are among the best students of each year, and thus are also those more interested to continue their research inside the academic world.

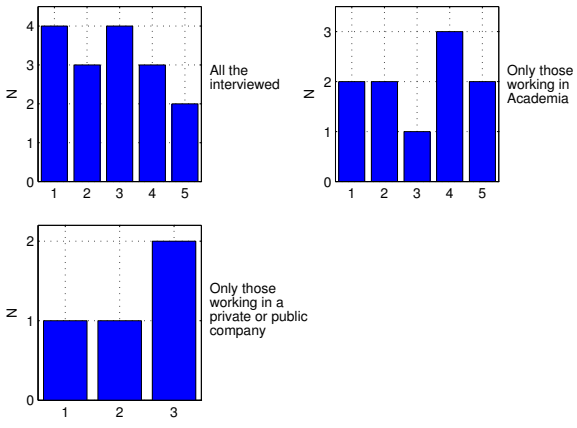


Did you apply for the ECMI certificate?

This question has not been completely understood: many students don't know what the ECMI Certificate is. Therefore, the advertisement of the certification was not at all sufficient, in spite of the fact that these students were coming from ECMI Centers.

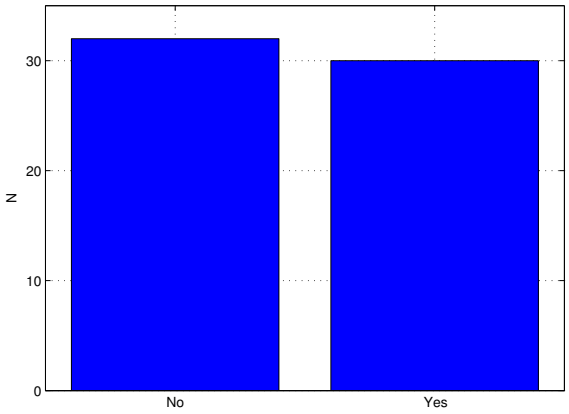


Only to those who got the ECMI Certificate: How much useful was the ECMI certificate to find your first job (1=useless 5=fundamental)?

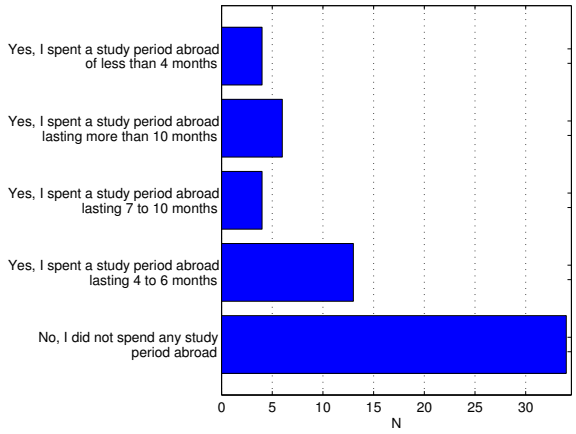


Only to those who got the ECMI Certificate: How much useful was the ECMI Certificate to improve the quality of your job? (1=useless 5=fundamental)?

The ECMI certificate looks more useful for academic life or further studies, and looks also more useful to find the first job than to improve its quality. But it should be taken into account that here the sample is small, and, as previously observed, the students who got the certificate are mainly those who continue with a PhD.

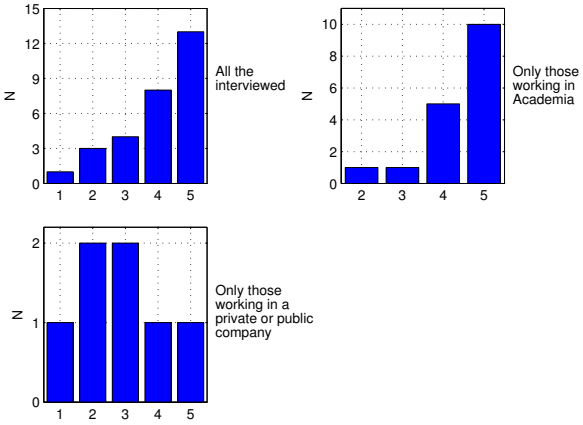


Did you follow any modelling seminar (apart from the MW)?

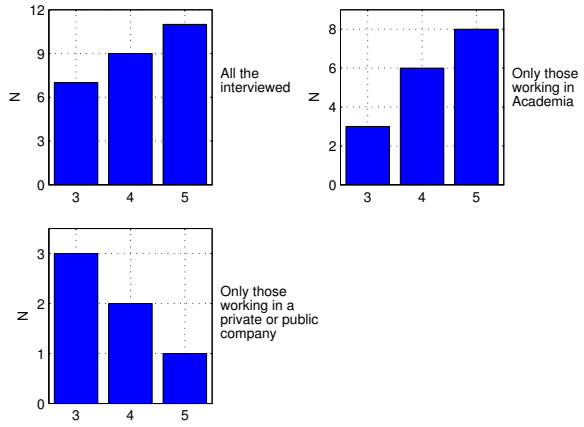


During the MSc, did you spend a period abroad?

Only one half of the interviewed have followed further modelling activities apart from the ECMI Modelling Week and have not spent a period abroad, confirming that many of these graduates have not followed the ECMI educational programme, which requires further modelling activities for at least 6 ECTS and to spend at least one semester in another ECMI centre.

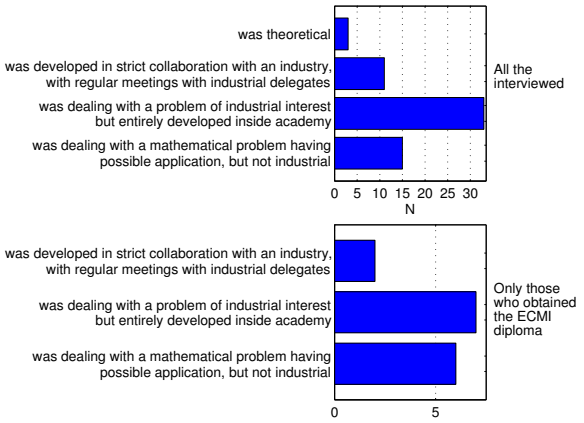


Only to those who did some modelling activity apart from MW: how much useful has been your training in Math Modelling in your job (1=useless 5=fundamental)?

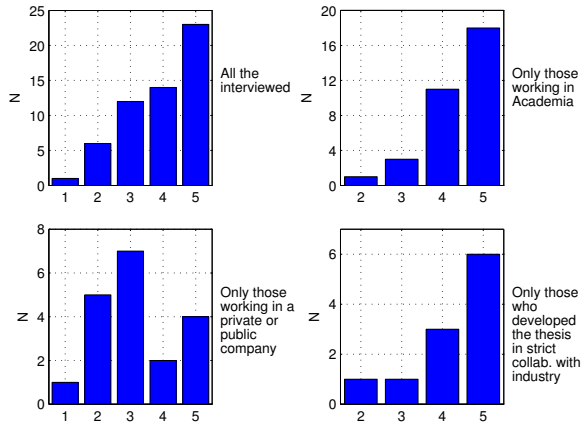


Only to those who spent a period abroad: How much useful was your period abroad to find your present job? (1=useless 5=fundamental)?

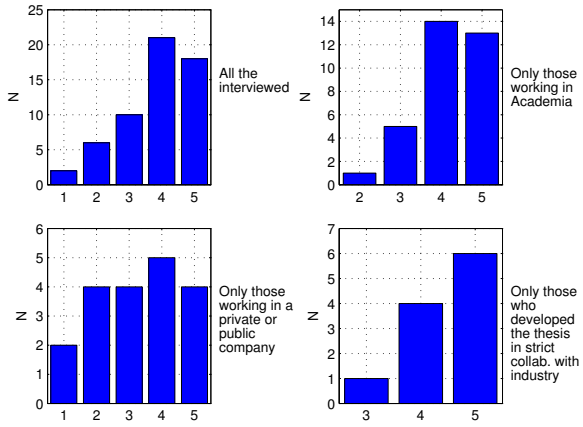
Like the ECMI Certificate, modelling and internationalization activities are more appreciated by those who are still studying or working in Academia, than those who are working in a company. This fact may reveal that those who work



Your MSc thesis



How much useful have been the competences developed during your MSc thesis to find your first job? (1=useless 5=fundamental)?

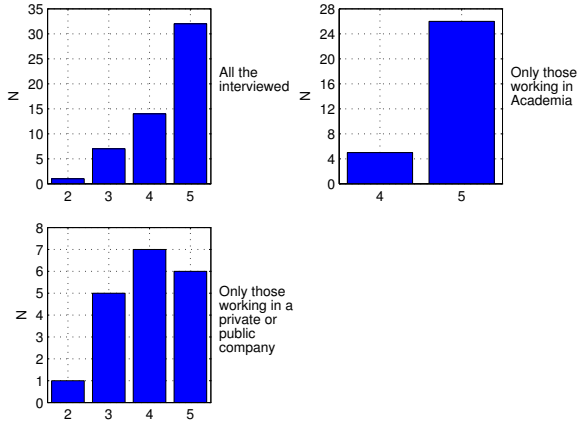


How much useful have been the competences developed during your MSc thesis to improve your job? (1=useless 5=fundamental)?

in a company, being mostly at their first job, are working in their country of origin and are performing works which are not much related with R&D activities, and even not much related with their university formation. This can be the reason why mathematical modelling and internationalization are not considered an added value from their companies.

This question was aimed to investigate how many students end their MSc with a truly industrial thesis. Even if the theses really developed in collaboration with an industry are a minority, a good percentage of those who declared to have got the ECMI certificate developed a thesis either in strict collaboration with an industry, or just inside the academic world, but dealing with industrial problems.

It turns out that the competences acquired during the development of the thesis, which in most cases was applied or industrial, are highly evaluated by these graduates as a good instrument both to find their first job and, even more, to improve its quality. This opinion is shared by both those who are working in Academy and in private companies. The satisfaction looks even stronger in those who developed a truly industrial thesis. This result reveals that the MSc thesis plays a central role in the working future of our students.



How much useful has been your overall university training to find your present job?

Even if some of the ingredients of the ECMI Educational Programme have not been much appreciated, in particular

by those who are working in a company, all the interviewed graduates give a positive evaluation to their overall university training, whatever job they are now running. The results of this survey thus suggest to the ECMI centers to advertise more the existence of the ECMI Certificate and to put particular care on the development of the MSc thesis, which looks a fundamental link to the future job of the students after their graduation. And, above all, the education should be really closely connected with serious industrial problems and with companies.

Alessandra Micheletti
Chair of the ECMI Educational Committee
Department of Mathematics
Universitá degli Studi di Milano
via Saldini 50, 20133 Milano
Italy
alessandra.micheletti@unimi.it